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ART. XIII.—*Note on the Rèh Efflorescence of North-Western India, and on the Waters of some of the Rivers and Canals.* —By HENRY B. MEDLICOTT, B.A., F.G.S., Professor of Geology, Thomason College, Roorkee.

[*Read* 15*th December*, 1862.]

THE following notes, very nearly as they stand, were forwarded in July, 1861, by post to the late Colonel Baird Smith, for communication to the Royal Asiatic Society. The address got defaced in the mail-bags; and the parcel, after lying for several months in the Dead Letter Office, found its way back to Roorkee. My observations have thus forfeited the advantage of correction and criticism from one so experienced in the subject to which they relate. Meanwhile, I have had some hurried opportunities of seeing and hearing more, and can thus make some alterations and additions.—H. B. M.

I have recently made several examinations of waters and soils for the information of the navigation departments of the north-western provinces and of the Punjab. Though undertaken for a purely practical object, the question contains matter of general interest, and may thus deserve record in *The Journal of the Royal Asiatic Society.*

It will be seen that the following investigation is far from being so full as the importance of the subject might warrant. I have not had an opportunity myself of studying directly the phenomenon discussed, and have thus had to depend, for that part of the question, upon the somewhat scanty and unsystematic observations of others. As, however, I may not be able for some time to add to the information thus obtained, I give it as it is; the facts at least will be valuable, and their publication may elicit further investigation.

Rèh is an efflorescence that occurs extensively in the less elevated districts of the *doabs.* Of two samples examined by me from the district of the W. Jumna canals, one gave 76 per cent. of sulphate of soda, and 24 per cent. of chloride of sodium; the other gave only 4 per cent. of the latter salt to 96 of the former. The *rèh*, therefore, seems to be chiefly glauber salt with a varying proportion of common salt. No doubt more numerous analyses would discover the occasional presence of other alkaline and earthy salts; indeed Dr. O'Shaughnessy gives a case in which the prevailing salt is carbonate of soda.

It would require very delicate experiments to determine at what precise proportion these salts begin to be prejudicial to vegetation. In the first of the samples alluded to the soil contained 30 per cent., and, in the second, 40 per cent. of *rèh*. But both these were collected off the very surface as samples of *rèh*, not of soil, and so they give no evidence on this point. The usual limit to the word *soil*, is the depth of ground worked up in cultivation. Among the specimens sent to Dr. O'Shaughnessy, we find the means of closer approximation. Two of those soils are given as containing but 5 and 8 per cent. of *rèh*, which, supposing it all sulphate of soda, would correspond to 2·8 and 4·5 per cent. of sulphuric acid. In both cases the ground was ruined for cultivation.

On the other hand it is well known that a certain amount of these salts forms a necessary element in all good soils. In combination with organic matter, the sulphates furnish some of the most nutritious classes of plants with their most nutritious elements.

I find from published analyses,[1] that a noted fertile soil may contain as much as 1 per cent. of sulphuric acid, a quantity far above that contained in the irrigation waters, the greatest proportion I found in these amounting to ·002436 per cent.

What brought this *rèh* into prominent notice was the fact that it was found to increase slowly but surely in the vicinity of the canals, under certain conditions. The extent of the destruction of good lands was so great that, in 1850, the subject was seriously considered by Government. Through the kindness of Colonel Turnbull, Superintendent of Irrigation, N. W. P., I am enabled to append extracts from the official correspondence on the subject.

In forwarding some samples to Calcutta for analysis, the Official General Superintendent of the Western Jumna Canal writes thus: October 1st, 1850.—" The attention of the civil and canal authorities in these parts has for a considerable period been directed to a change which is taking place in the soil in various parts of the country irrigated by these canals. A white efflorescence has made and is making its appearance in various places, destroying all vegetation with which it comes in contact. The barren space gradually increases in area, and speedily the ground thus affected is deserted by the cultivators, who forthwith assail the civil officers with petitions for remission of revenue . . . . I trust I have supplied you with sufficient data for the elucidation of the following points:

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[1] Art. Agricultural Chemistry. " Enc. Brit.," 8th edition.

"I. Whether the *rèh*, or natron, is entirely inherent in the soil, and evolved merely by the excessive use of water practised by cultivators irrigating from the canal; or whether the chemical properties of the water tend to create the noxious substance.

"II. The nature and quantity of substances hostile to vegetation existing in the various specimens of soil, and their comparative intensity in the several surface and corresponding subsoil specimens.

"III. Whether the waters taken from the Sorreput and Bhotuk districts has become impregnated with this poison during its course from the Jumna, and to an extent calculated to create the deposit of natron, and to deteriorate the produce of lands to which it may be delivered.

"IV. The nature of the repellant which destroys or neutralises the noxious elements contained in the soil, or held in solution in the water; and whether you can suggest any substance easily obtainable, and of so low a price as to be within the reach of cultivators; in other words, a practical remedy, partial or complete.

"V. Your opinion as to the probable increase or otherwise of the deterioration of soil under the following circumstances:

"*a.* As at present, unlimited water and scanty manure.

"*b.* Limited use of water and liberal nourishment to land.

"*c.* Abstinence from irrigation and manure.

"The subject is one of great interest in these times; when a great increase of canal irrigation is on the point of being given to the country."

The following is from Dr. O'Shaughnessy's memorandum in reply: 15 December, 1850.—"I give the results in rough, reserving details for a future communication if required.

"Waters:

"No. 1. Below Dadoopoor Bridge: is remarkably pure. It does not contain more than 1 part in 16,000 of solid matters and this chiefly a calcareous salt with traces of sulphate of soda.

"No. 2. Canal waters, Paneput district: still more pure than No. 1.

"No. 3. Contains $\frac{1}{8000}$ of solid matter, partly organic, partly saline, the salts being of lime and soda.

"There is nothing whatever in these waters which could prove prejudicial to crops of any kind.

"Subsoils:

"No. 1. Khotuk district: 2 feet below surface, yields saline matter 1 part in 500. This saline matter is composed of muriate and sulphate of soda and lime. No nitre or carbonate of soda.

"No. 2. Jagu, Paneput district: 2 feet deep; yields barely a trace of saline matter in 500 parts.

"No. 3. Boola, Kurnaul district: 1 foot below surface; not 1 part in 1,000 of saline matter.

"No. 4. Jooah, Paneput: 2 feet below surface; same as No. 2; little or no salt.

"From the above facts it is clear that there is nothing in the under-soil in question which could prove injurious to vegetation.

"Soils:

"No. 1. Rohtuk district. Saline matter 4·90 per cent.; chiefly common salt, sulphate of soda, and muriate of lime, a trace of nitrate of lime and soda.

"No. 2. Jagu, Paneput: saline matter 20 per cent.; carbonate of soda in abundance, with sulphate and muriate of soda and lime.

"No. 3. Boola, Kurnaul: saline matter 8·9 per cent.; chiefly sulphate of soda and common salt.

"No. 4. Jooah, Paneput: saline matter 22·80 per cent.; sulphate and muriate of soda and lime; little or no carbonate or nitrate of soda.

"Soil so strongly contaminated with saline matter, as the above results show to be the case, are unfit for cultivation.

"There is no chemical substance procurable, within the means of cultivators of any class, capable of neutralizing the deleterious effects of these saline matters.

"But, wherever drainage can be accomplished, the thorough working up of the surface soil, with abundance of water from the canal, will, if continued for a couple of seasons, dissolve and carry away the noxious salts. But the drainage must be efficient and rapid, otherwise the salt will merely dissolve, and be again deposited in the same place."

In these remarks Dr. O'Shaughnessy very clearly expresses, for all practical purposes, the very same facts that I have now arrived at, that the salt does not exist to an injurious extent in the irrigation water, nor in the sub-soil, and that it only exists at the surface. He, moreover, unhesitatingly pronounces that a special system of irrigation and drainage would *cure* the affected lands.

The data furnished to him did not admit of his saying more, and others did not follow up his statements to their legitimate conclusions. The question is still as much in debate among the canal officers as it was in 1850. I have now referred to me from the Baree Doab Canal the very same question that we have just seen answered by Dr. O'Shaughnessy for the case of the Western Jumna Canal; accompanying a sample from Mazby, the tail of the Lahore branch. It is dated, 5th July, 1861. "As the canal passes through a tract of land full of *kullur*, it is desirable to ascertain the quantity of this salt the water takes up." The notion expressed in this request is extensively believed among natives, and through them has found acceptance with a few Englishmen, who are blind enough to object to canal irrigation. It was to refute the supposition with facts that the analysis was asked for. There can be no better reason for offering the case for publication. Dr. O'Shaughnessy's analysis never got into print, and was unknown to the engineers of the Baree Doab Canal.

In endeavouring to account for the indecision I have pointed out, I think I have detected the one small link that was wanting to give full acceptance to Dr. O'Shaughnessy's recommendations. It is a link that, as I have said, he had not the means of supplying; and I may even add, that it is only apparently essential to the practical question at issue. It is this:—*Where does the rèh come from?* This is the question that I now find stopping the way. *The one fact*, that was eagerly accepted from Dr. O'Shaughnessy's report was, that the canal water was harmless;—a fact, however, qualified by the figures of the same document, showing the presence of sulphate of soda (the prominent element of rèh) in canal water. Thus, I find the Superintendent of the Western Jumna Canals, in stating the case to the civil authorities, writes, 30th January, 1851:—"The communication referred to distinctly settles this most important question. Mr. O'Shaughnessy not only states that the canal water in the Paneput districts, where the efflorescence is most abundant, is remarkably pure, and contains no matter in any way prejudicial to the crops which it irrigates, but actually recommends its use, in conjunction with a regular system of drainage, to free the country from the noxious salts which at present cover its surface."

Had Dr. O'Shaughnessy been able (or, perhaps, thought it necessary) to state, that drainage would *prevent* as well as *cure*,—that even a small decimal per centage would surely, and in no very long time, accumulate to 3 or 4 per cent., or more, according to the circumstances of the ground in relation to evaporation and drainage—a definite opinion on the point would surely have long since been adopted and put in practice. This small want has for so long shaken confidence in the case and kept it in abeyance. It is still questioned whether the *rèh* cannot be mysteriously elaborated from the soil, or be brought from some unfailing store below ground.

Considering the many hundred miles of canal (principal and secondary) that have been constructed since 1850, it is a matter for most serious regret that so important a point should have been left in doubt.

The evil, however, went on increasing. In 1856–1857, Mr. Sherer, a civil officer, was deputed to report upon the affected districts, with a view to the reduction of the assessment. He gives a very distressing account of the poverty and disease produced by the noxious effects of the *rèh*, with its cause, upon the cultivation and upon the inhabitants; and he gives a long list of estates which are gradually advancing to a like state with the worst.

It is from Mr. Sherer's MS. Report (lent to me by Colonel Turnbull) that I have gathered some facts connected with the appearance of the *rèh.* The unexceptional fact that appears from these notes is the invariable association of *rèh*, canal, and swamp; at least this is the case with the lands *that have recently been impregnated,* and which were the object of Mr. Sherer's inquiries. Under the general name of *swamp,* I include not only ground actually under water, but also ground that is saturated immediately below the surface; what Mr. Sherer speaks of as "*choyul* or dry swamp."

For example:—"Bal Jatan. In land that is accessible to irrigation only by the process of *dal* (raising the water), the soil looked tolerably well in the central part, but as the slight elevation closed off towards the low lands again, the crops looked sickly and the colour of the soil indicated the presence of rèh." . . . . .
"I draw attention to the fact, that the lands where there is a slight rise above the general level of the estate are the only ones that enjoy anything like immunity from injury."

"Didwaree. Beautiful crops crown the high lands that rise from the sides of the canal, but as soon as the banks rise the land falls, and all appearance of cultivation passes gradually away."

Such is the uniform tenor of Mr. Sherer's observations. But he, too, seems to have been at the mercy of pure conjecture regarding the origin of the rèh; thus, after noticing some *kullur*-land (land that had of old been abandoned to the rèh), he exclaims, "Where is the theory that this *rèh* is produced by excessive irrigation and *dofussli* farming? Here is land which has never been ploughed and never been irrigated, producing the noxious salts in far greater quantity and virulence than the cultivated lands of the same estate." I must not stop to notice the fallacy of this argument. I will presently consider the case of kullur-land.

Thus, then, the canal is the abundant cause of the swamping, either by the copious irrigation it affords, or by the unavoidable percolation through its bed raising the level of saturation for a considerable distance on each side; or, at least occasionally, by obstructing the natural drainage of the country. Mr. Sherer calls attention to two cases of this, thus:—"Boorshaum: this flood is also caused by the Munameh Rajbuha, which, running along the south of the estate, holds up all the water." "Munder: much swamp, particularly just round the village, by water held up by the Kusandhu Rajbuha," and with this swamping comes the *rèh*.

Now, then, we have got a proximate cause of the evil. It is a direct inference, that if the swamping is prevented, if the drainage is provided for, the *rèh* will not appear. It is only at the surface that we *can* control the water, so there is no choice of remedies. The only other remedy would be to remove the *cause* of swamping, *i. e.*, the stopping and clearing away of the canal, a remedy which of course no one will dream of.

If this point be fully established—and, as far as I have had the means of judging, it is inevitable—the investigation need *not*, for practical purposes, be carried further. The question that has for years kept the matter in abeyance seems to me, in a great measure, futile. It does not signify in the least whether the substance is in the water originally, or whether the water finds it in the ground below the surface, or even the imaginary case of its being evolved from the soil. The evident facts of the case go to prove, that the injurious accumulation of it is the slow result of prolonged concentration, of which the essential concomitant is swamping. A small amount of consideration further shows that the accumulation is due to evaporation from a surface which is, for a great portion of the year, more or less saturated with water, or which is almost or entirely dependant on evaporation for relief from drainage-water. Such is the state of the rèh land described by Mr. Sherer, upon whose observations I have chiefly to depend; they seem to have the merit of being unprejudiced in any way. The latter condition alone would be sufficient in time and without excessive flooding. It may, indeed, be said, that if the rèh comes from the canal water, it would be desirable to reduce irrigation to a minimum. This would, no doubt, in many cases postpone the evil day, but no more. The other remedy, which is the very opposite of this one, would have to be adopted at last; so why not start with it?

As a matter of interest the question of the origin of the rèh is worth attention. As far as the facts before me are a guide, I am inclined to the opinion that the canal water is *the chief* source of the salt. I am now speaking of the lands newly affected.

The canal water is *a known* cause; it *must act* to its full extent; it affords an *inexhaustible*, an ever-renewed supply, and it may be adequate to the result. Let us put the case in its strongest light. It is *undeniable* that, supposing the soil, the subsoil, and the rock to be perfectly free from these salts, the very result before us would eventuate under the conditions described, and from the canal water alone. We have seen that a soil containing 30 parts of sulphuric acid in a 1,000 of soil produces barren rèh land. We may take 30 parts of sulphuric acid in 1,000,000 of water, by weight, as the quoted proportion contained in the canal water.

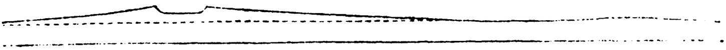
Taking 2 as the specific gravity of sulphuric acid, it would require an evaporation of 5,000 inches deep of water to convert 10 inches cube of soil into rèh soil. I have no authority for giving an approximate figure to the annual evaporation for this part of India; any one who has spent a hot season in upper India will allow that it must be very great. I am not, however, now aiming at exactness, but rather at a free illustration of the case; if, then, we take 10 feet, or 120 inches, as the annual evaporation, we should get rid of our 5,000 inches in about 40 years. Fifteen feet is the amount estimated by Massey for the tropical seas ("Physical Geography of the Sea," edition 1860, p. 37), where, be it remembered, the atmosphere is but little below the point of saturation. To this computation, moreover, a very large correction has to be applied in our case; a correction that will at least compensate for any exaggeration of the evaporation; we have been supposing the area to become impregnated by evaporation from its own surface only, a case that probably never occurs; it is almost a necessary condition of these low, swampy lands, that they should receive the washings of the surrounding area, it may be many times greater than that of the land actually destroyed. Mr. Sherer more than once calls attention to this fact of drainage water bringing *rèh* with it.

Something such as I have just described being a necessary process under certain conditions, it must be accepted as at least an auxiliary cause when these conditions are seen to exist. The other cause assignable is the existence of a supply of these salts, more or less concentrated, at some depth below the surface, and from which the *rèh* is derived by the change produced by the canal in the water-circulation near the surface. In some parts of the country there seems to be little doubt of the presence of such a source: I will presently refer to it. When it exists to *any great extent*, it could not fail to be detected by proper observation.

The supposition vaguely put forward by some, that the elements of these salts exist, to the full extent, latent in the *soil*, and are developed by irrigation, is quite inadmissible. The assertion must be proved. No chemical operation could be simpler than to show the presence or absence of the ultimate components of these salts.

The very few facts we possess from the districts affected show a rapid decrease in the proportion of salt with increase of depth. At two feet below a surface containing 40 per cent. of salt, the subsoil contained but 0·167, and at four feet, only ·144 per cent.; corresponding to ·094 and ·081 of sulphuric acid;—a quantity less than might be expected in any clay,—a proportion, however, greater than that in the canal water. This latter fact, surrounded by the *opinion* that the necessary action of the water in percolating through the ground would be to reduce the salt in it to an equal proportion with that in the water, may be put forward as evidence that the quantity in the subsoil had formerly been greater than what has been found in the samples examined, and that it has in the process of percolation furnished the *rèh* at the surface. To such an argument I can only answer, that unless in cases where facts are brought to support the supposition, it is irrational to accept it in opposition to what I have shown to be, necessarily, at least a partial source. It is well known how retentive clays are of minute portions of these salts; it does not at all follow, because a clay gives up all its soluble ingredients when it is well powdered and freely washed in a beaker glass, that it would do so under the natural conditions we are discussing. Moreover, we know that the percolation of water through strata is very irregular, according to slight variations in the texture and composition of the rock.

What gives the most plausible encouragement to the notion that the *rèh* originates in the ground below the surface, and has only an indirect relation with the canal water, is the well-known fact that in many parts of the country, more particularly I believe, if not exclusively, along or near to the southern limits of the quondam alluvial deposits of the Gangetic plains, wells are frequently sufficiently briny to afford an available supply of salt. Where such is the case, it would be natural to expect that any cause such as the canal (see diagram) which would bring this



briny water nearer and sufficiently near the surface, would result in saline efflorescence. Here, too, we may demand of those who put this forward as a general cause, to the exclusion of the canal water, that they should bring some evidence of this being a general phenomenon. If it were so, evidence could not fail; a necessary concomitant would be, that in the canal *rèh* districts the well-water should be decidedly and universally more saline than the canal water. If such were the rule, or even frequent and to any *marked extent*, it could hardly fail to have been noticed in connection with the *rèh*. It may, however, be so slight as to be only discoverable by chemical means, as in the case at Roorkee, to be presently noticed. Were this cause very decided, we should also, I think, find the amount in the subsoil to be above the normal proportion instead of below it, as we have seen in the cases examined. Indeed, this cause would seem to be inadmissible, or but very subordinate, in many of the cases most insisted on by Mr. Sherer, when within a few dozen yards or less from the canal the lower ground is *rèh* land. Within this limit the water direct from the canal must largely predominate over any water contaminated from below.

I have but one tolerably satisfactory observation to bear upon the question under discussion. Within the station of Roorkee *rèh* has made its appearance. This pretty and salubrious station is situate between the Ganges canal and the Solani river, at the southern angle of their intersection. It is built upon the ground that rises rapidly from the broad valley of the Solani. Some of the houses stand upon the very edge of this rise; in one case the garden is on the lower level, in the khadir of the Solani; it is the garden belonging to the Director of Irrigation, N.W.P. Eight years ago, and subsequently, the garden was not noted as less productive than others. Now, and latterly, it is markedly so, and the cultivation of it has been in some measure abandoned. *Rèh* shows plentifully on the surface; and at present, in the end of March, 1862, the water lies at a depth of only four feet. The actual amount of this *rèh* on and near the surface of the ground necessarily fluctuates greatly with the state of the weather; a smart shower would take away *excess* of it down to the water level below, to be drawn up again by continued evaporation. Samples taken on the 8th April, 1862, gave in the soil scraped from the surface 2 per cent. of *rèh*: in 4 inches cube takèn from and *including* the surface, there was but 0·4 per cent.; and in the subsoil at the water level but 0·2 per cent. of the dried sample. The water in the garden-well (*d*, pl. V) gave but 0·007 per cent. To compare with this, I examined the water of three other wells: the relative position of each is exhibited on the accompanying plan; showing also the levels of the ground and of the water in each, reduced to the level of the masonry floor of the Solani, under the aqueduct. The level of the canal-floor and of some other points are also given. The level of the water in the wells is more or less affected by the constant drawing of water; this is very marked in the well *c*. The usual depth of water in the canal is from six to eight feet. The results are shown together in Table A. The wells *a*, *b*, and *c*, are distant from the canal 500, 4,000 and 3,500 feet; in each the water is well removed from any sensible influence of surface evaporation; and in each the amount of *rèh* is but slightly different from that in the canal water; rather *less* than *more*; but the difference is within the limit of variation in the canal water itself. The well *d* is between the canal and *c*, at 1,400 feet from the canal. In it the amount is more than trebled; it stands in *rèh* land: this amount would no doubt be greater were there free communication with the ground immediately around; it is a pucka well, the masonry walls going several feet below the water level.

TABLE A.—Parts in 10,000, by weight.

	Ganges Canal.	Well *a*.	Well *b*.	Well c.	Well *d*.	Surface *d*.	Soil *d*.	Subsoil *d*.
Sulphates ..	0·1745	0·2441	0·0174	0·0417	0·347	155·0		
Chlorides ..	0·0357	0·0122	0·0953	0·0837	0·349	145·0		
Totals ..	0·2102	0·2563	0·1127	0·1254	0·696	200·00	40·00	20·00

The evidence of this case seems to me very strongly in favour of the supposition I have advanced. It cannot be reasonably maintained that the subterranean conditions at *d* are different from those at *a*, *b*, and *c*. The superficial features are due to a totally different class of causes from those by which the strata were formed. It would be beyond the limits of probability that a saline deposit

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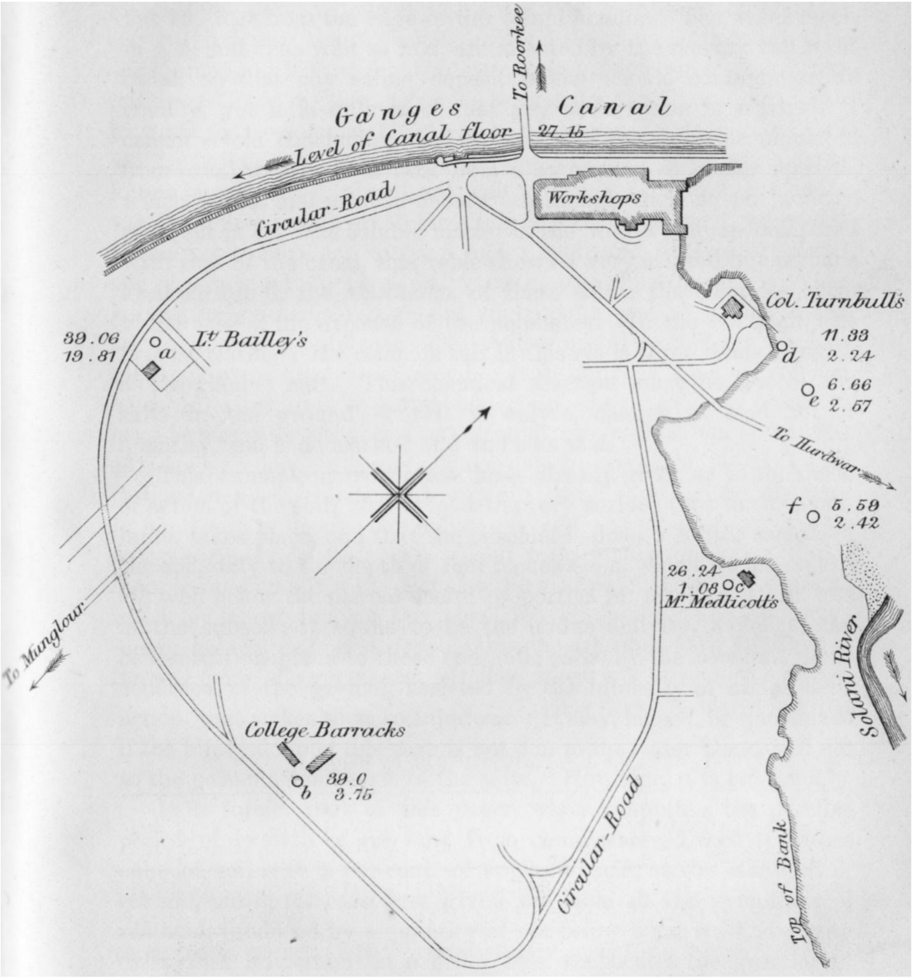

PART OF ROORKEE STATION.

N.B. The upper figure refers to the ground and the lower one to the water level, reduced to the level of the masonry floor of Solani at aqueduct.

Scale, 1,200 Feet One Inch.

(To face p. 356.)

should occur below *d*, and not at the other places. Even in superficial conditions the well *c* is but slightly different from *d*, being but 200 feet from the edge of the Solani khadur. The water levels in *a*, *b*, and *c*, as well as in *d*, are affected by the rise and fall in the canal, so that any saline deposit below should contaminate all equally, yet it is only in *d* that any such action is marked. I cannot avoid concluding that the *rèh* at *d* has been accumulated from canal water, or *at least from a solution of no greater strength*, which is the chief point in debate. Although there is no increase apparent in the *total* soluble matter in the well-water as compared with that of the canal, this table shows a very marked but perhaps local change in the *constitution* of these salts: the chlorides seem to increase at the expense of the sulphates. In the *rèh* itself this is most marked; the common salt in this *rèh* is three times as much as the glauber salt. This chemical reaction must be due to the salts in the ground; but it is only a change of kind, not of quantity, and is as marked at *b* and *c* as at *d*.

This example corroborates those already given as to the mode of action of the soil; that it is at the very surface that the accumulation takes place, and that the mischief is done. A fair sample of the soil, only to the depth of four inches even, shows an amount of *rèh* well below the normal useful proportion for a soil, and still less in the subsoil; it seems to be the undue activity, mobility, and concentration given to these energetic salts by the constant damp condition of the ground, assisted by the intensity of atmospheric action, that makes them so injurious. It may, indeed, be questioned if the injury done in this case is not due to the water alone, and not to the poisonous influence of the salts. However, it is *rèh* land.

In a former part of this paper, when computing the possible period of growth of *rèh* land from canal water, I took 10 inches cube of soil with 3 per cent. of sulphuric acid, as the standard of *rèh* soil, but in the case just given we have all the symptoms of *rèh* land, produced by a quantity of *rèh* below what we know may exist with advantage in a soil. This complicates the question of cure not a little. It seemed possible to reduce a large excess of soluble salts by free irrigation, with rapid removal of the water; it would not be at all so easy to deal with so small a *proportion* as we have just shown may act with serious effect; the first water that touches it carries it into the soil, and its proportion there is so small that the water has very little power to remove it. At the same time these results give us strong hopes of the effects of persevering drainage, without the troublesome and wasteful process of flooding. In the well *d*, which, as I said, is protected from the ground near the surface by impervious walls, we still find the water considerably charged with *rèh;* if this water were compelled to move on, the circulation must, even without the assistance of irrigation, reduce the *rèh* within harmless limits, but this action will be somewhat slow: an obvious fact which makes its adoption as a preventive the more urgent. The further investigation of the question ought to show the depth from the surface at which the water's level begins to influence the surface in this way, with due attention to the circumstances of soil, exposure, and contour.

I do not at all wish to put forward this mode of origin of the *rèh* as universal. There can be little doubt but that in many parts of the country the ground is, to some extent, overcharged with salts, but I am pretty well convinced that in many cases the cause is what I have described. It would be a matter of much importance to be able to distinguish the several causes; for the remedy, though the same for all, should be adopted accordingly. When the cause is purely superficial, it might be sufficient to maintain a very moderate amount of circulation in the drainage water, at but little below its natural level, especially if the remedy were adopted in time; whereas in the case of a subsoil charged with salts, it would be necessary to keep the water level well below that depth at which it comes within the influence of atmospheric changes. If this cause existed in a marked degree, it would evidently be hopeless to attempt to keep it down by ensuring the moderate washing of the few upper inches of soil. I believe that the examination of the subterranean water will always enable us to detect this cause. The whole subject is one that calls for judicious experiment.

The existence of *kullur* land long before the canals were constructed, and in places where the canal water can never reach, has greatly contributed to maintain the doubts as to the formation of *rèh.* I have scarcely any analyses or field observations to guide me in discussing this point, but there are some general considerations that seem to me of much weight. In localities where the river and the well water is sweet, as is the case in some kullur districts, and where in consequence the ground cannot be largely impregnated with salts, is it not a physical impossibility that the surface, which once or twice a year gets well drenched with rain water, should remain charged with highly soluble alkaline salts if the drainage be efficient? May we not then conjecture that these *kullur* lands are natural areas of inefficient drainage—lands more or less dependent upon evaporation for the removal of surface waters? For this it is not necessary that they should always be the lowest parts of the country; upland hollows present the same conditions. Under these conditions *rèh* would slowly accumulate, whether from an original small excess in the soil itself, or aided by contributions from the higher ground around. The difference between *kullur* land and canal *rèh* land is, that in this there will be no limit to the accumulation, unless carried off by drainage.

I would again remark, that this attempt to find the origin of the *rèh*, is of little direct consequence to the question of its prevention or cure. In every case noticed, which are, I confess, but few, we have seen that, immediately below a surface copiously charged with it, the amount present was below what may be considered desirable in a good soil. Wherever the *rèh* comes from, drainage is the only and the efficient cure.

I wish, also, to repeat, that my views as to the common origin of the *rèh* have been adopted from small evidence (as the reader may judge), and in opposition to the universal opinion of those connected with the canals. Some of the objections offered present, I confess, grave difficulties to my theory. For instance, an experienced canal officer writes—"I have seen what appeared to me to be *rèh* on the edge of high baugur land, with a drop of some 30 feet to the khadur below." It would require very peculiar conditions to make this a case of inefficient drainage, but it is not impossible. We have seen what a very small total proportion of salt in a soil is sufficient to produce a *rèh*-surface. Again, I am told that, on the very edge of a drainage cut, there may sometimes be seen a line of *rèh* efflorescence ("stratum of *rèh*"). This fact *may* be but an illustration of my argument; this line may have been a more porous band of subsoil, in which percolation was just sufficient to keep the exposed sectional surface damp, and along which, therefore, evaporation would concentrate any soluble element. Every one may have noticed such bands of percolation in natural and artificial sections. At all events, these examples illustrate the uselessness (? mischief) of observations isolated in time and from surrounding circumstances, and without the object of testing some particular hypothesis.

When passing through Lahore in February last, I made some incomplete observations upon the *rèh* land about Anurkullee; some of the facts are puzzling. I cannot say what the relations of the ground are with regard to *thorough* drainage, but *rèh* showed freely on plains where the *surface* drainage was complete, as, for instance, along the sides of the road, where it runs in embankment several feet high by the ground selected for the new Horticultural Gardens. In the low ground close by, I picked up some facts that may illustrate this and other difficulties. In the lowest parts of the hollow area, there was a *rich* crop of young wheat growing. It was irrigated from a well in the centre. In several parts of the field there were small patches white with *rèh*, and with nothing growing on them, though they had evidently been tilled and sown; they were a few inches higher than the surrounding surface, and were thus removed from the irrigation. Three inches cube of soil (including the surface) taken from one of these patches, gave the very high proportion of 3·8 per cent. of *rèh* in the air-dried soil. A few yards off, among the wheat, a similar quantity of soil gave the very low proportion of 0·2 per cent. Having no other facts to guide me, I can only make the following surmises: from the very small proportion of salt in the irrigated ground, I conclude the water to be tolerably pure, evidently sufficiently so for advantageous irrigation. The amount of *rèh* due to the whole area, cannot be anything like that found on the isolated patches; the same process that removes the *rèh* from the general surface to distribute it temporarily through the subsoil, effects its special accumulation on these spots; they remain dry from day to day, and the results of evaporation can thus accumulate, the supply being constantly renewed at the expense of the common stock, which, on the whole is not probably an abundant one. The appearance of *rèh* on higher places, as on the roadside, may be due to the same action. The phenomenon reminded me of that often seen when a saline solution is allowed to dry up in a vessél, the salt seems as it were to creep up the sides.

This *rèh* contained 88 per cent. of sulphates, 7 per cent. of chlorides, and 5 of other salts.

On the whole, we cannot but look forward to canal irrigation as the cure for all this. It places a powerful agency within our control. It would be especially applicable when it can be brought to bear upon the more elevated *kullar* lands. In those more parched districts of Upper India, it seems to me doubtful if such lands ever get a thorough soaking from the surface to the water level below; there is no such thing as natural subsoil drainage. The first few drops of rain dissolve all the surface salts, and are soaked into the ground; the dash comes; as much as can runs off, nearly as pure as it falls, as far as soluble ingredients are concerned; and the rest is dissipated before enough has been absorbed to establish a free connection with the water-stratum below. Thus, time after time, the same *kullur* makes its appearance. Free irrigation, with drainage, would very soon catch it and dispose of it.

Such, at least, are the opinions suggested to me by the cursory and indirect examination I have been able to give to the subject. I subjoin tables, showing the results of some experiments on the contents, in solution and suspension, of the water of these rivers and canals.

TABLE B.—Showing the principal soluble ingredients in 10,000 parts of water.

	1.	2.	3.	4.	5.
Locality.. ..	Ganges, Hurdwar.	Ganges Canal, Roorkee.	Ganges Canal, Roorkee.	Jumna, Fyzabad.	E. J. Canal, 96th mile.
Time of collection	13 June, 1861.	22 May, 1861.	4 July, 1861.	1 June, 1861.	1 June, 1861.
Carbonate of lime .	0·4731	0·57	(?) 0·57	0·1600	0·4285
Sulphates	0·10293	0·1747	0·12507	0·2428	0·0914
Chlorides	0·00539	0·0357	0·00232	0·0174	0·1500
Totals ..	0·58042	0·7804	0·69739	0·4202	0·6699

	6.	7.	8.	9.	10.
Locality.. ..	E. J. Canal, 96th mile.	Ravee, Madhopore.	Ravee, Madhopore.	Baree Doab Canal, Neazbeg.	Thames, Twickenham.
Time of collection	1 June, 1861.	See *note*.	See *note*.	5 July, 1861.	
Carbonate of lime .	0·2142	0·4514	(?) 0·4514	0·4357	1·97
Sulphates	1·1462	0·2042	0·4325	0·14244	0·38
Chlorides	0·8440	0·0285	0·0348	0·01832	0·25
Totals ..	2·2044	0·6841	0·9187	0·59646	2·60

NOTE.—A gallon of water was operated on in each instance. The sulphates and the chlorides are estimated as soda salts, which they were proved to be almost entirely in some cases, by more complete analysis. No. 6 is given as a warning in collecting; two gurrahs of the water were sent, filled at the same time and in the presence of the canal officer; in checking the analysis from the second vessel, I found this enormous discrepancy. I repeated the analysis to make sure of the fact; the second gurrah must have been independently charged with salts. The sample No. 7 was collected in bottles on the 1st and 18th September, 3rd and 15th

October, 15th November, and 1st and 15th December; No. 8 on the 15th January, 1st and 15th February, 15th March, and 15th April. I have given an analysis of Thames water for comparison. I made a more complete analysis of one example as a clue to the others. The water from Neazbeg, the tail of the Lahore branch of the Baree Doab Canal, gave in 10,000.

Silica	·0114
Carbonate of lime	·3700
Carbonate of magnesia	·0657
Chlorine	·0113
Sulphuric acid	.0801
Lime	·0368
Magnesia	trace
Soda	·0310

The water from the College well (*b*, Table A) also showed a trace of lime and magnesia in the portion dissolved in water after evaporation.

The analyses in this table are not numerous enough, nor accompanied by sufficient collateral observations, to exhibit any rule in the variations indicated in the proportions of the soluble ingredients of water taken at the same place at different times, or at about the same time, from different places on the same stream. These variations most probably depend upon the prevailing changes of the weather as causing rainfall or evaporation, and consequent dilution or concentration of the water. The canals receiving little or no drainage water below the heads would probably exhibit this very markedly; thus, the decided decrease in No. 9 as compared with Nos. 7 and 8, may be due to rainfall on or before the 5th of July, for the highly soluble salts, the sulphates and the chlorides, any means of supply that might have originally been present in the ground cut by the canal would have been rapidly washed away, giving an example on a large scale of what may be done with it in detail. An increase in the carbonates, as seems indicated by 4 and 5, might continue for an indefinite time, if the stream passed over much *kunkur*, the process of solution being very slow.

Table C.—Silt Estimates, parts in 10,000.

No.	Date	Hurdwar	Asufgurh	Roorkee	
1	4 May, 1856 ..	2·03	·38	3·37	
2	1 May, 1857 ..	·09	..	1·28	
3	1 May, 1858 ..	..	..	..	
4	22 May, 1861 ..	..	..	3·82	
5	5 June, 1856 ..	6·05	7·34	5·19	4 feet of water at Roorkee
6	10 June, 1857 ..	6·88	..	2·75	4 feet of water at Roorkee
7	1 June, 1858 ..	3·41	..	3·85	
8	13 June, 1861 ..	13·65	..	..	
9	4 July, 1856 ..	14·50	8·00	11·79	
10	4 July, 1857 ..	10·45	..	5·17	
11	2 August, 1856	23·10	13·30	26·10	
12	2 August, 1857	17·03	..	5·83	
13	2 Sept., 1856 ..	6·89	81·00	7·66	
14	1 Sept., 1857 ..	5·39	..	..	
15	4 Oct., 1856 ..	clear	..	·85	
16	1 Oct., 1857 ..	1·98	..	1·00	
17	5 Nov., 1856 ..	·61	3·30	2·20	6·5 feet of water at Roorkee
18	1 Nov., 1857 ..	·44	..	..	
19	1 Dec., 1856 ..	·20	1·43	·55	
20	1 Dec., 1857 ..	clear	..	1·32	
21	1 Jan., 1857 ..	..	·45	1·67	
22	1 Jan., 1858 ..	clear	..	1·32	
23	1 Feb., 1857 ..	1·02	·12	1·26	
24	1 Feb., 1858 ..	..	..	..	
25	1 March, 1857..	..	1·27	·99	
26	1 March, 1858..	..	..	..	
27	1 April, 1857 ..	·37	·45	·82	
28	1 April, 1858 ..	..	..	..	

Table C.—Hurdwar is where the Ganges leaves the Simalik hills to enter upon the plains; the stream is much more rapid there than lower down. Asufgurh is on the Ganges, about eighteen miles below Hurdwar. Roorkee is eighteen miles below Hurdwar, on the Ganges Canal. These estimates are of course exclusive of the soluble ingredients. If the single series of estimates from Asufgurh for 1856—1857 can be trusted, they seem to indicate approximate equality with Hurdwar during the period of low water; a very decided diminution during the period of greatest flood, involving a very considerable deposition along the bed and low branches of the river below Hurdwar, and a marked increase about the rise (from snow-water) and fall, before and after the rains in the mountains have charged the river with sediment, the lower reach of the river thus preying on its muddy banks. No. 13, from Asufgurh, may be questionable, for all the samples from there I had to depend upon a native messenger.

The proportion of silt in the canal water at Roorkee, as compared with the head, seems to depend upon the depth of water, producing either silting-up or erosion.

Some cases in Table D show how very indefinite such silt-estimates must sometimes be; samples collected by myself at same time, in same way, and with equal care, showing a difference of a third.—See 6 and 7.

TABLE D.—Occasional Silt Estimates, parts in 10,000.

No.	Date.		
1	4 July, 1856	Solani at Roorkee, a 3 feet flood	47·30
2	16 July, 1856	„ „ 3·5 feet flood	93·90
3	19 July, 1856	„ „ 6 feet flood	80·00
4	19 July, 1856	„ „ same time as No. 3	87·10
5	22 Sept., 1856	„ „ 5·5 feet flood	68·50
6	31 July, 1857	„ „ 9 feet flood	228·80
7	31 July, 1857	„ „ same time as No. 6	148·50
8	1 June, 1861	Jumna, at Canal head	1·04
9	10 June, 1861	„ „	3·05
10	1 June, 1861	E. Jumna Canal, 96th mile	10·50

2nd May, 1862. H. B. MEDLICOTT.